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Implementation of Optimized Deep Learning-Based Early Flood Detection Management System and Avoidance System

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I. Introduction

As a result of rising pollution and greenhouse gas emissions, there has been a significant surge in the frequency of natural disasters such as earthquakes, floods, and tsunamis in various parts of the world. Among these disasters, flooding is a prevalent phenomenon. While satellite images enable us to accurately forecast rainfall and cyclone trajectories, it is imperative to have real-time monitoring data, such as flow, precipitation levels, and water levels, to make informed decisions about flood prevention measures. The extent of flood damage expenses is closely linked to the lead time provided before the onset of flooding, underscoring the importance of flood monitoring and prediction in mitigating the costs of flood damage. In certain countries such as the USA, the utilization of advanced technology has resulted in a decrease in casualties. However, countries that lack technological and economic advancements are unable to achieve the same level of success. In present times, expensive equipment is required to address these issues. This particular model offers a solution that is both cost-effective and highly reliable, utilizing limited computational power to detect impending floods with the aid of sensor networks. The effectiveness of this approach is largely attributed to the Internet of Things (IoT), which is a network system comprising embedded electronics, software, and sensors that can remotely send and receive data.

The "Early Flood Detection and Avoidance System" is a smart system that keeps track of a range of variables of natural occurrences in order to predict floods. Currently, flood risk management systems are primarily concerned with predicting floods and generating maps to identify vulnerable areas. To address the limitations of traditional methods, artificial intelligence (AI) algorithms, machine learning, and computer vision techniques have been proposed. The primary objective of this project is to utilize a deep learning approach to construct a flood monitoring and detection system that can detect floods. The primary aim is to establish an early warning system for floods that can automatically detect and report flood incidents to both the Local Government Unit and citizens. The precise goals of this work includes detecting the current level of water in rivers at various locations, predicting river water levels, warning residents about floods, and updating government officials about the situation of the floods, and informing government officials about the situation.

II. Literature review

At present, there exist multiple systems aimed at detecting floods and issuing alerts [1], allowing individuals to quickly evacuate to safer areas. The variations among these systems are based on their predictive technology for flood detection, communication methods for alerting people, and the transmission chain for delivering the flood warning message to the general public. Another crucial aspect to consider is the practical viability of these systems to function as intended, given the potential obstacles such as power outages, network tower failures, and lack of internet connectivity [2].

Saravanan et al.[3] Design a system that can be installed either on a dam or along riverbanks to continuously monitor multiple variables such as water level, temperature, precipitation, and humidity. The collected data will be compared against preset threshold values, and if any abnormal readings are detected, an alert will be generated and displayed on a website as well as transmitted via SMS. Gomathi et al. [4] A flood detection and prevention system utilizing IoT technology is being proposed. The system employs sensors to gauge water levels, humidity, and temperature, and transmits real-time data to both the cloud and users via a mobile application. The system serves as an effective means of alerting individuals prior to a flood, enabling them to take necessary precautions. Naveena et al. [5] In this context, the new model was examined, which entails transmitting sensor data, including temperature, humidity, water level, water flow, and ultrasonic readings, to the cloud via an IoT device. If certain environmental thresholds are exceeded, an alert will be sent to the appropriate authorities who will then inform residents of flood-prone areas. This system facilitates the proactive efforts of both public and private organizations to address the situation before it escalates, enabling them to prepare for emergencies and implement mitigation strategies.

Dyah et al.[6] suggested system comprises two primary components, namely, the lava flood detection subsystem and the disaster communication subsystem. It employs a modified automated rain gauge, a uniquely designed vibration sensor, the Fuzzy Tree Decision algorithm, ESP microcontrollers that enable the Internet of Things, and disaster communication tools such as WhatsApp, SMS, and radio communication. Additionally, several studies have been conducted on flood management methods, including an analysis of flood forecasting technologies [7], the use of machine learning for flood prediction [8], and flood mapping and assessment systems [9]. Chang et al. [10] An advanced flood warning system was created by merging a hydrodynamic model, k-means clustering algorithm, and support vector machines (SVM) to identify typhoon flood incidents and provide precise predictions of both the scope and depth of flooding. Additionally, fuzzy-logic-based systems have gained popularity and are utilized to anticipate river water levels and trigger early alerts in the event of a flood. Moreover, flood detection through harmonic analysis and change detection of multi-temporal data has been achieved with an accuracy rate of 80%. In addition, the Chobe floodplain in the Caprivi region of Namibia was mapped using a novel change detection and thresholding (CDAT) technique applied to SAR imagery. This method was described in [13]. Another approach, proposed in [14], utilized a Bayesian network to integrate various remotely sensed data sets, including multi-temporal SAR intensity images and interferometric-SAR coherence data, with ground information such as geomorphology, roads, and buildings. Meanwhile, a Multilayer Perceptron (MLP) based on back-propagation has been employed in [15] to predict floods using rainfall time series data and water levels in a weir that could potentially impact urban areas. Similarly, flood modeling has been carried out using a Wavelength Neural Network (WNN), as documented in [16].

Laura [17] A multi-modal deep learning technique was suggested to identify floods in social media posts. The method utilizes the metadata and visual data typically found in social media posts to detect floods. The approach employs a CNN to extract visual characteristics and a bidirectional LSTM network to extract semantic characteristics from the textual metadata. We evaluated the technique on images obtained from Flickr, which includes both visual and metadata information, and compared the results obtained using both data types, only visual information, and only metadata. This study was conducted in the context of the MediaEval Multimedia Satellite Task. Hafis et al. [18] The use of Unmanned Aerial Vehicles (UAVs) has been employed to create an automated imaging system capable of identifying areas that are inundated from aerial images. In order to detect landmarks like roads and buildings from the captured images, the Haar cascade classifier was utilized in a case study. The landmarks that were extracted were then added to the training dataset to train a deep learning algorithm. The experimental results indicate that the buildings and roads in the images can be detected with an accuracy of 91% and 94%, respectively. Furthermore, the overall accuracy of the input case study images in classifying flooded and non-flooded regions is recorded as 91%.

III. Research gap identified

- Flood detection has yielded favorable outcomes using Traditional machine learning algorithms like SVM. However, as the size of the training dataset expands, the complexity of this model also increases substantially.
- In addition, SVMs require tuning in order to identify the optimal kernel function for training. The parameter optimization that pertains to the kernel function is the crucial element that impacts the classification performance.

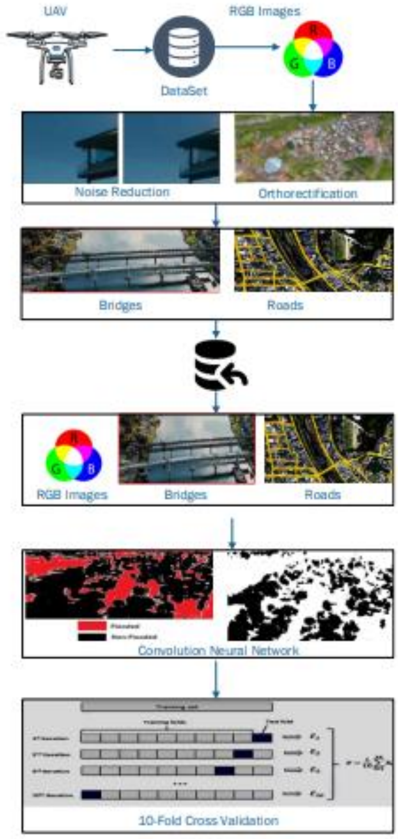
Consequently, researchers are turning to deep learning, including RNN and CNN models, to manage large datasets like the one in the present study, especially for image classification and segmentation problems. CNN, a multilayer neural network, is a widely used and well-established framework in deep learning. While CNN has been utilized previously to classify data obtained through remote sensing, its application for flood mapping has not been extensively explored. As a result, this study employs CNN to identify flood areas in Chennai from aerial images acquired by UAVs.

IV. Objective of this study

. It is crucial to detect and monitor flooded regions in rural areas for evaluating the harm caused to vital infrastructure, identifying and locating residents, and devising evacuation routes for those affected by the disaster. The suggested system guarantees the identification of significant landmarks, such as roads, buildings, and bridges, which are then linked to georeferenced maps to facilitate informed decision-making after the calamity. The main contributions of the proposed work is:

a. To acquire the images using Road way flooding dataset;
b. To enhance the acquired images using contrast limited adaptive histogram Equalization(CLAHE) and Bilateral filtering;
c. To extract and Select landmarks features using GLRM and ant colony optimization for detection;
d. Training the model on the dataset followed by perform Flood detection using optimized hybrid classifier (CNN+LSTM).
e. To evaluate the performance of the proposed work with the conventional techniques

V. Block diagram



VI. Methodology

In this work the Road way flooding dataset. The dataset obtained consisted of RGB images that contained a certain degree of distortion, which is a typical feature of satellite or aerial imagery. Additionally, the surface of the Earth exhibits topographical variations, and the distance between displayed features in images obtained from satellites, UAVs, or aerial cameras may not be entirely accurate or reflective of actual ground conditions due to the angled view. The extent of distortion in the images increases in proportion to the topographical diversity of the terrain. To extract meaningful insights from these images, it is crucial to eliminate the distortion. To achieve this objective, the "orthorectification" method of image processing was utilized, which eliminates the impact of tilts and terrain in the images, resulting in a planimetrically accurate image. The resulting orthorectified image displayed features captured in their authentic positions with a consistent scale. Additionally, the captured images might contain environmental noise such as air pollution, dust, smoke, and fog. To reduce noise in captured images, a Bilateral filtering technique with high de-noising capability and mathematical accuracy is employed. Bilateral filtering is a commonly used order-statistic filter in digital image processing that can effectively eliminate unwanted noise while preserving the edges of features. Image preprocessing is a necessary initial stage that enhances the quality of input images and prepares them for further processing in subsequent steps. To account for variations in images, data preprocessing is carried out, which includes improving the brightness and size of collected images through contrast limited adaptive histogram equalization and cropping out unwanted background regions/surfaces. Random image cropping and patching are used for data augmentation in the training process of proposed CNNs to generate labels and detect floods. Additionally, landmark features are extracted from preprocessed images using a supervised learning approach, such as Gray Level Run-Length Matrix features, for feature selection. Only bridges, buildings, and roads can be considered as landmark objects. These landmarks are extracted and combined with raw RGB images to create the feature space for training an optimized CNN+LSTM (Long short-term memory) classifier. The optimization process used is chaotic biogeography-based optimization (CBBO). The classifier is then tested on new test images to evaluate its flood detection capability. The performance of the system is evaluated using a confusion matrix derived from the validation process. The results obtained from testing on both pre- and post-flood classes are promising. This system can be used by flood relief and rescue workers to quickly locate flooded areas and rescue stranded individuals.

The deep learning model known as CNN has garnered much attention from researchers due to its versatility across various fields. It has surpassed other machine learning techniques and is now a prominent part of both ML and computer vision applications. CNN is a feed-forward network with subsampling and alternating convolutional layers. It's worth noting that the development of deep CNN has focused on its ability to process 2D data, such as images and videos, which is why it's also known as 2D-CNN. This type of CNN has a powerful forward neural network capable of accurately extracting features and learning complex objects from large datasets of labeled data. One of the researchers, [1], proposed various dimensionalities of CNN for different purposes. They were the first to propose ID-CNN for handling sequential data and also contributed to the development of 2D-CNN, which has gained popularity and been utilized in various fields, such as flood detection prediction.

Convolutional Neural Networks (CNNs) are frequently utilized in the recognition of images and videos and are a category of deep neural networks. In the context of the implementation of an optimized deep learning-based early flood detection management system and avoidance system, CNNs can be used to analyze satellite images, drone footage, or other visual data to detect changes in water levels and identify potential flooding areas. Convolutional Neural Networks (CNNs) are specifically designed to automatically acquire and extract features from images, which makes them highly suitable for tasks that involve object detection, segmentation, and classification. By using a CNN in a flood detection and avoidance system, the model can be trained on large datasets of images containing flooded and non-flooded areas, allowing it to recognize patterns and predict the likelihood of a given area flooding in the future. To optimize the performance of the CNN, various techniques can be used, such as data augmentation, transfer learning, and hyperparameter tuning. These techniques can help improve the accuracy and efficiency of the model and make it more suitable for real-world applications.

A. *Performance Analysis*

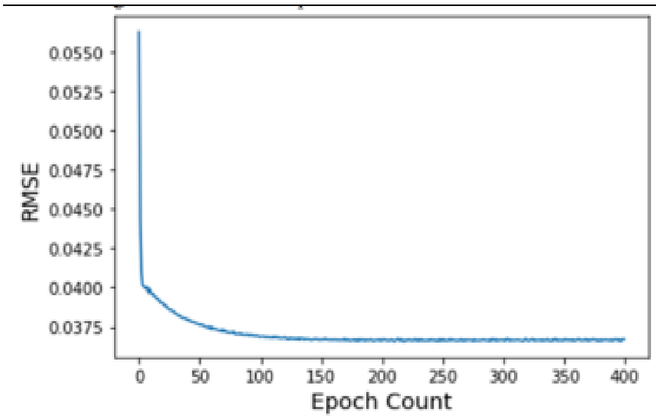


Figure 1. Variation of RMSE value over the training epochs

Table I provides a summary of the model qualities obtained using various training epochs. The highest level of model quality was attained when training for 400 epochs.

Training Epochs	100	400
RMSE value (m)	0.037	0.034
Best Fit %	83.3	85.4

Table 1. Model performance.

B. Results

However, in general, the implementation of such a system could have a significant impact on flood management and prevention. Early detection of floods using deep learning algorithms can provide timely warnings to people living in flood-prone areas, enabling them to evacuate or take necessary precautions to prevent damage. This system can also provide data for flood modeling and forecasting, which can be useful for city planners and emergency responders. Furthermore, an avoidance system can help prevent damage to infrastructure and other property. By using real-time data and analysis, the system can determine the best course of action to avoid the flood, such as redirecting traffic, shutting down power plants, or moving people and resources out of harm's way. Overall, the implementation of an optimized deep learning-based early flood detection management system and avoidance system has the potential to save lives and prevent significant damage in flood-prone areas.

VII. Conclusion

The implementation of an optimized deep learning-based early flood detection management system and avoidance system can significantly improve flood management and reduce the damage caused by floods. It is feasible to create a flood detection system that can predict potential flood hazards before they reach critical levels, by leveraging sophisticated technologies like artificial intelligence, machine learning, and deep learning to process vast amounts of data. The implementation of such a system requires a collaborative effort between various stakeholders, including government agencies, research institutions, and technology companies. It is crucial to develop a robust data collection and analysis infrastructure to support the system's accurate and timely predictions. The system must also be able to communicate with relevant authorities, emergency services, and the public to ensure swift and effective action in the event of a flood. One key aspect of an optimized flood management system is an avoidance system. By using real-time data from flood detection sensors, it is possible to generate predictive models and provide accurate information to the public about the potential flood risk in their area. This information can help people make informed decisions about evacuation or other safety measures to take. Overall, an optimized deep learning-based early flood detection management system and avoidance system have the potential to significantly reduce the damage caused by floods and save lives. It is crucial to invest in research and development in this area to develop effective flood management solutions that can cope with the increasing frequency and severity of floods caused by climate change

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